Dedication

This guide is dedicated in memory of Dr. Howard D. Brown, former Research Coordinator of the Potato Chip Institute International, who stimulated interest and inspired much of the work leading to development of this report.

Dr. Brown brought to this project an extensive educational background of undergraduate and doctoral studies at Michigan State, Wisconsin, and Chicago, and a lifetime of service at other universities. Prior to his association with the Institute, he was 5 years with the University of Illinois and the Experiment Station, 10 years associate professor at Purdue and associate of the Experiment Station, 28 years professor at Ohio State and the Agricultural Experiment Station, and the past 2 years as professor emeritus, Ohio State. He had broad experience in food technology including soil fertility, effects of nutrient levels on the vitamin content keeping qualities of processed foods, processing and handling frozen foods, vegetable science, and potato chipping.

Dr. Brown was a man of foresight and ideals, and a devoted scientist. He visualized this guide as a much needed aid to the industry. This dedication recognizes his untiring efforts toward the production of a practical and technical report as represented by this document.

an Industrial Waste Guide to the

Potato Chip Industry

Prepared by the
Committee on Potato Chip Wastes of the
Potato Chip Institute International
in cooperation with the
National Technical Task Committee
on Industrial Wastes

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Division of Water Supply and Pollution Control
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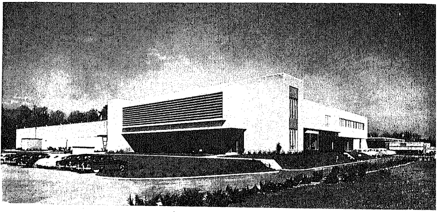


A modern potato chip plant.

Foreword

The Potato Chip Industry is anxious to cooperate with other industries and governmental agencies to effect the reduction or elimination of objectionable wastes so that they will not contaminate or otherwise render the water supply of our Nation objectionable.

The wastes produced by the potato chipping industry, unless mixed with sanitary sewage, are seldom, if ever, contaminated with pathogenic organisms which affect public health. The problem is, therefore, one of the elimination of wastes from streams so that the animal and plant life therein may flourish, thus producing a greater abundance of aquatic food and at the same time furnish recreation for fishermen, and aesthetic waterways and otherwise increase the utility of our water resources for beneficial uses. To further conserve resources, the possibility for the economical utilization of the wastes is also explored.

This "Industrial Waste Guide to the Potato Chip Industry" is intended primarily to aid management and operators of the industry to reduce, utilize, and suitably dispose of processing wastes. It will also be helpful in acquainting consultants and regulatory personnel with the nature and source of the potato chipping wastes and the progress that has been made in the treatment of such wastes.

Members of the Committee on Potato Chip Wastes that helped to prepare this guide are located in nearly every geographical section of the country, thus problems peculiar to climate have been considered. The committee was also selected because of special experience in waste disposal and utilization. Some of the suggestions contained herein should, therefore, be useful to nearly every chipper regardless of geographical or urban locations.

The following is the committee personnel: H. D. Brown, Research Coordinator, Potato Chip Institute International; Gil DuVernay, Food Technologist, The Frito Co., Nicolay-Dancey Division; R. D. Foster, Chief Engineer, Red Dot Foods, Madison, Wis.; Barney Hilton, Food Technologist, H. W. Lay & Co., Atlanta, Ga.; Cliff Marshall, Engineer, Nalley's Inc., Tacoma, Wash.; Ralph Porges, In Charge, Waste Treatment Studies, Field Operations, Water Supply and Pollution Control, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio; and Paul A. Xander, Director of Research and Development, Wise Potato Chip Co., Berwick, Pa.

Material for the guide was obtained in large part from publications prepared by the Waste Treatment Studies Unit of the Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio.

The guide was reviewed by the Potato Chip Institute International through interested supporting activities of Harvey F. Noss, Executive Vice President. It was submitted to the Public Health Service by the industry representatives on the National Technical Task Committee on Industrial Wastes.

The National Technical Task Committee on Industrial Wastes is composed of representatives from the Nation's leading industries concerned with solving difficult industrial waste problems. Its objective is to perform certain technical tasks pertaining to industrial wastes in cooperation with the Public Health Service and others concerned with improving the quality of the Nation's water resources. Preparation of the guide was one of the tasks assumed by the Potato Chip Industry in carrying out this objective.

This is the seventh of a series of Industrial Waste Guides prepared by the National Technical Task Committee in cooperation with the Public Health Service.

Introduction

This publication includes suggestions and procedures which chippers can employ to economically reduce or eliminate the wastes from their operations which may ultimately reach fresh water streams either through their own waste disposal and utilization facilities or through those owned and operated by governmental agencies.

In facilities wholly operated by chippers, these procedures may be as simple as disposing of the untreated wastes on agricultural lands where they also serve the dual purpose of raw product conservation and soil enrichment; not to mention the possible value for crop irrigation. If spray irrigation is utilized the publication includes details for separating the solids which may clog irrigation nozzles.

Finally, directions are given for the removal and, in some cases, the utilization of soluble solids.

The procedures utilized for the separation of soluble and insoluble wastes from the liquids can in most instances be employed to reduce the B.O.D. (biochemical oxygen demand) of wastes which are disposed of through local municipal waste disposal systems. By calculating the costs involved, chippers, regardless of location, can determine whether to eliminate a part, or most of the BOD before allowing it to enter the municipal system.

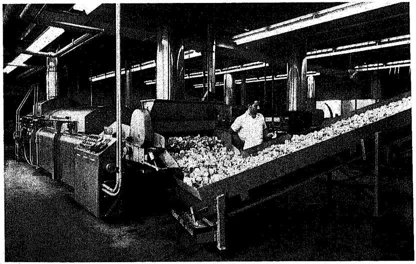
Because of economics involved, considerable attention is directed to the use of various irrigation systems and stabilization ponds even though most chippers cannot currently employ such systems.

Costs and sewage plans have not been included in this guide because of the great variations involved. The Research Department of the Potato Chip Institute International does, however, have a limited amount of cost figures which will be supplied on request. No two chippers will have identical problems. It is obvious, therefore, that this guide should be construed as an aid and not as the whole and final answer to waste disposal problems.

Insofar as possible the guide includes factors which cause deviations from normal waste loads and suggestions for meeting these deviations.

It is probable that newer and better methods of waste disposal will be discovered in the foreseeable future. When such improved procedures are available in sufficient number it is the thought of this committee that a revised guide will be published.

Figure 1.—Processing potato chips in a plant in Ohio.

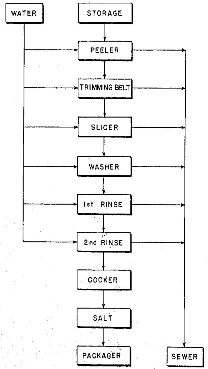


Description of Process

The processing of potatoes to potato chips involves essentially the slicing of peeled potatoes, washing the slices in cool water, and rinsing, partially drying, and frying them in fat or oil (fig. 1).

Potatoes are generally received for storage at the chipping plant in 100-lb. sacks or in large wooden containers. The potatoes are fed to a peeler where high-speed, abrasive, rotating discs remove the skin. The peeled potatoes are washed, trimmed, and then sliced, 15 to 20 slices per inch. The slices are washed, generally in a tank or trough of water, and twice rinsed to remove the starch to prevent matting or sticking of the chips. After partial drying, the slices are fried in deep-fat cookers. The chips are then salted and packaged (fig. 2).

Figure 2.—Flow diagram.



Raw Materials and Products

The potato is the most important item in the science and art of chipping. It must produce a chip with eye appeal and have a solids content that assures a profitable enterprise. High sugar content and nitrogenous portions of the potato combine during cooking to cause the undesirable dark chip, a condition which is controlled by selection of potato variety, growing conditions and proper storage.

For economical processing, the potato should have a high density which can be determined by analysis or estimated from the specific gravity. Since specific gravity can be more easily assayed and is indicative of production volume, the potatoes are usually received at the plant with their specific gravity recorded. The Department of Agriculture states (5) that the correlation between specific gravity and dry matter has usually been found to be very high with correlation coefficients varying from 0.85 to 0.95. It indicates that the following formula developed by Von Scheele, Svensson, and Rasmussen seemed to approach analytical results:

Percentage dry matter = 211.04 × specific gravity − 207.709 (1).

However, analytical results provide the best data.

The starch content may be likewise estimated from the specific gravity, by the formula given by Von Scheele et al. (5)

Percentage starch = 199.07 × specific gravity − 201.172 (11)

The estimated solids and starch content of potatoes at the given specific gravities is found in table I (1).

Potatoes may be assumed to contain about 20 percent solid matter and 80 percent water; the starch content ranges from 65 to 75 percent of the dry weight (12).

Table I.—*Calculated solids and starch content of various specific gravities (Von Scheele et al.)* (5)

Specific gravity	Solids	Starch	Starch in solids
	Percent	*Percent*	*Percent*
1.06	15.99	10.16	63.3
1.07	18.10	12.15	67.2
1.08	20.21	14.15	70.0
1.09	22.32	16.14	72.3
1.10	24.44	18.14	74.2

Other information indicates that the solid matter may average as high as 25 percent (10). The variety of potato influences these values although the former figure might prove a more realistic average. The varieties best for chipping include Russet Rural, Russet Burbank, Smooth Rural, Irish Cobbler, Kennebec, Sebago, Katahdin, Delus, Merrimack and Saco (1) (9) (13).

The next important raw material is the cooking oil, almost always a high-grade vegetable product. The least significant ingredient is salt.

Chip production will vary with solids content of the potato. From 1,000 pounds of the so-called standard potato (20 percent dry solids), chip production will approximate 250 pounds with an average moisture content of 2½ percent. The finished chip also contains about 40 percent absorbed oil. With potatoes having greater than 20 percent dry solids, chip yields will generally increase.

Source and Volume of Wastes

The primary sources of wastes are shown in figure 2. Wastes are derived from the peeling, trimming, slicing, and rinse operations. Other wastes accrue from clean-up, small amounts of waste oil, and occasionally sanitary sewage.

Table II presents plant data on waste flows based upon a unit production of 1,000 pounds of potatoes.

Table II.—*Plant operation and wastes discharged per 1,000 lbs. of potatoes processed* (11)

Plant	Month	Employees (number)	Potato chips* (pounds)	Waste flow (gallons)	B.O.D.		Suspended solids	
					p.p.m.	lbs.	p.p.m.	lbs.
A	July	0.9	240	2,480	730	15.0	820	24.3
B	December	1.3	260	2,020	1,560	26.2	2,140	35.9
C	October	1.0	240	2,000	1,850	30.8	2,190	36.4
D	December	2.3	255	1,450	1,200	**14.5	1,700	**20.4
Average		1.4	250	1,990				

*Average weight of oil on finished chip is 40%.
**Much solid material was removed manually and did not reach the sewer.

Composition of Wastes

Waste from a potato chip plant varies with the season as it influences the types of potatoes used and with the method of processing. The greater the solid content of the potato, the greater the oxygen-demanding properties the gross waste material will have. For example, the following hypothetical condition is presented:

Specific gravity	Solids (percent)	B.O.D. p.p.m.* (whole potato)
1.06	15.99	72,400
1.07	18.10	82,000
1.08	20.21	91,600
1.09	22.32	101,100
1.10	24.44	110,700

*Based on 0.453 pound B.O.D. per pound dry potato solids.

Waste handling practices are also important. If solid materials such as peelings and small pieces of potatoes are removed for disposal other than sewage, the waste load will be reduced.

Table II contains data from several plants showing B.O.D. and suspended solids. Plant A (table II) at the time of study was handling during the summer (July) a potato with low solids and thin peel; it will be noted that the pounds of B.O.D. per unit potato was low. Plant D was removing solid material from the waste flow, with a corresponding reduction in the strength of the waste discharged. Plants B and C were studied in the fall (October and December) and the waste values were in close agreement with a much higher B.O.D. per 1,000 pounds of potatoes.

The process was evaluated on a dry-solids basis and an estimated waste calculated from the solids discharged compared with the actual waste collected in the sewer. The results of this evaluation are shown in table III. The data presented are based on 1,000 pounds of potatoes. Column 1 shows the dry weight of 1,000 pounds of potatoes; column 2, the pounds of chips produced.

The B.O.D. of a potato was determined in the laboratory (11). Two individual runs were made with the following results:

	Raw potato		
	Solids (percent)	B.O.D. p.p.m.	Pounds B.O.D./lbs. Solids
A	18.57	84,000	0.452
B	18.70	85,000	.455
Average	18.64	84,500	.453

Since chips will average about 2½ percent moisture, the dry weight is presented in column 3. The average oil content of the chip is 40 percent, so the oil weight shown in column 4 was subtracted from the net dry weight of the chip in column 3 to show the dry potato solids ultimately sold (column 5). The difference between the dry weight of the potatoes (column 1) and the dry solids produced (column 5) represents the pounds of dry solids lost (column 6). It will be observed at the bottom of table III for each pound of dry solids, a B.O.D. of 0.453 pounds will be exerted. Based on the pounds of dry potato solids lost (column 6), the pounds B.O.D. discharged can be determined.

TABLE III.—*Solids balance and B.O.D. relationship per 1,000 pounds potatoes* (11)

	Dry weight [a]	Chips produced [b]	Dry weight	Oil in chip [c]	Dry solids produced (3)−(4)	Solids lost (1)−(5)	B.O.D. of solids lost [d]	B.O.D. in sewer
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
A	177	240	234	96	138	39	17.7	15.0
B	210	260	254	104	150	60	27.2	26.2
C	200	240	234	96	138	62	28.1	30.8
D	210	255	249	102	147	63	28.5	*(14.5)
Average	200	249	243	100	143	56	25.4	25.0

[a] Dry-solids variation probably due to seasonal variation.
[b] 2½% moisture.
[c] Chip contains 40% oil.
[d] B.O.D. per pound solids =0.453.
*Omitted from average as much solid material removed manually. Replaced by adjusted value of 28.1.

as indicated in colmn 7. Column 8 gives the B.O.D. obtained from the sewage analysis divided by the number of thousands of pounds of potatoes used. Comparison of the results of determining the waste load by the two independent methods (columns 7 and 8), is extremely good. Deleting results for plant D because of manual removal of much of the solids, adjusting for the remaining data, and then averaging columns 7 and 8, the calculated average B.O.D. based on solids lost is 25.4 pounds while that obtained from the waste in the sewer is 25.0 pounds.

Suspended solids will average about 32 pounds for each 1,000 pounds potatoes processed. Based on a suspended solids population equivalent of 0.20 pounds, this amounts to the suspended matter discharged by 165 people.

A representative condition, the average in table III, that might well be used for a general case would start with potatoes having 20 percent, or 200 pounds solids per 1,000 pounds potatoes. Dry solids produced would equal 143 pounds, indicating 56 pounds of solids lost. The B.O.D. of the solids lost would be 25.4 pounds and should represent the amount found in the sewer. Since the B.O.D. normal to sewage waste from one person is 0.167 pound per day the population equivalent, based on B.O.D. for each 1,000 pounds of potatoes processed with the above characteristics, would be about 150.

The above method of estimation will provide a quick means of evaluating wastes from a potato chipping plant. For example, assuming that a plant processing 20,000 pounds of potatoes with a solids content of 22 percent, the dry solids handled will amount to 4,400 pounds. Assuming a chip production of 26 percent of the raw potato, the chip poundage produced would be 5,200 or a dry weight of 5,120 pounds. The oil content may be estimated at 40 percent of the gross weight of chips or 2,080 pounds. The dry solids produced would amount to 3,040 pounds. In this example, the d solids discharged to sewerage would be 1,360 pound The pounds of B.O.D. wasted would be 616 pounds equivalent to a population of 3,700.

A previous study of potato chip processing wast (10) indicated a population equivalent (B.O.D.) 65 per 1,000 pounds of potatoes. This estimate is lo when compared to the present value of 150 P.E. p 1,000 pounds. However, that study was made on batch process and some solid materials such as sprou and possibly peelings were disposed of to a dump. Th report (10) stated that the data was limited to a sing plant and might not give accurate indications of was loadings for application to other plants.

Several reports of wastes from potato dehydratic processes appear to be of interest since these wast may compare grossly to the wastes from chippir plants. Gray and Ludwig (7) show dehydration wast to contain 40 pounds of B.O.D. per ton of potato processed, amounting to 120 population equivalents p 1,000 pounds. Jones (8) reports 12,000 populati equivalents for 40 tons of potatoes, or 150 P.E. p 1,000 pounds; a check with the present study. D Martini, Moore, and Terhoven (6) reported on tw separate dehydrating plants. One plant discharged 3.2 pounds of B.O.D. per 100 pounds of potatoes, or 19 P.E. per 1,000 pounds. The other plant showed 4.5 pounds per 100 pounds, or 274 P.E. per 1,000 pound of potatoes.

The variation in these data probably results from th types and maturity of potatoes used and the processin methods employed. A smooth potato with thin ski produced less waste than that from a rough potato wit thick skin. Evaluation of the wastes from these pro esses on the basis of dry solids lost to sewerage woul bring these studies to a common basis and might ind cate a closer correlation.

Pollution Effects

The discharge of untreated potato chip wastes has several undesirable effects upon the receiving watercourse. Floating solids create a visual nuisance while decomposable organic sludges drain available dissolved oxygen from the flowing waters. The high turbidity interferes with light penetration thereby reducing normal algal life. The organic matter in the wastes may undergo rapid decomposition utilizing oxygen that may be reduced to low levels in the stream. The solids coat the stream bottom breaking the normal food chains for stream biota. Fish habitat may be destroyed, or at least damaged. The sum total effect may be the creation of a stream not available for maximum beneficial use.

Suggestions for Effective Waste Prevention or Reduction

The volume of water used is a matter of importance both from the standpoint of cost of the water and of waste disposal. Generally, a reduction in volume decreases sewage disposal costs. Some attempts have been made to reuse water, particularly that clearer portion of the rinse waters. Filtering (centrifuging better) of the water prior to reuse has not proven practicable as the starch particles rapidly clog most filter media. Application of the counter-current principle appears promising especially since the initial machines and peelers and the first potato wash before peeling do not require high quality water. Considerable water could be saved by pumping the final rinse waters to the wash tank and using the wash tank overflow to feed the peeler and then discharging it to sewerage. No filtering or water conditioning would seem to be necessary.

The method of housekeeping also influences the waste load. Where peelings, and solid wastes are removed manually for dry disposal, the waste load is reduced appreciably. At one plant the B.O.D. of the waste was reduced to nearly 50 percent of that estimated from the solids balance. Other plant operators, mostly in large cities, feel that disposal to sewerage facilitates the handling of waste solids.

Starch could be settled from the waste stream by proper sedimentation units. Development of by-product use of this starch is a distinct possibility, but at present the cost to remove the starch is too high for value returned.

Soluble solids removal

One of the methods for the removal of soluble solids; i.e., sugars, amino acids, and minerals, is their conversion into algal masses in stabilization ponds.

A method for removing amino acids and the purification of the same has been patented by Xander et al. (14).

Grease

A grease trap is useful in separating grease (from other wastes) which arises during machinery cleaning operations.

Feed value of recovered solids

Solids recovered have a feeding value for dairy cows approximately one-third that of alfalfa (2). Dairy cows utilize the raw as well as cooked product but the wastes must be cooked when fed to hogs to achieve maximum nutritional value.

The wastes can also be dehydrated and fed as supplements to other foods. A typical analysis of the dried product is as follows: Moisture 10 percent, carbohydrates 68 percent, protein 9.5 percent, minerals 4.0 percent, fiber 7 percent, and fat 1.5 percent.

Waste Treatment and Disposal

Potato wastes unless mixed with sanitary sewage are seldom, if ever, contaminated with pathogenic organisms which affect public health. Furthermore, they afford valuable organic materials as well as some minerals which if applied to farm lands may ultimately lead to increased yields. The use of the liquid wastes for irrigation may also offer certain economies when the plant is located in a farm area.

Flood, furrow and ditch irrigation

In a limited number of cases, i.e. where chipping plants are located within 1 to 3 miles of available farm land the combined liquid and solid wastes (do not include sanitary sewage) can be spread by flood, furrow or ditch techniques to land which may be set aside specifically for this purpose, or with additional planning, the wastes may be used for irrigation during the cropping season (4). Timbered land will absorb moisture more quickly than cropped or fallow lands. Western sands and gravel, especially in arid sections, have a great capacity for moisture.

Irrespective of the procedure employed it is essential that moisture and wastes shall not be allowed to stand stagnate for more than 24 hours (4). If this simple precaution is observed there will be no trouble from odors or undesirable insect infestations. This perhaps is the cheapest method of waste disposal (see fig. 3).

Figure 3.—Ridge and fu[rrow] row irrigation.

Spray irrigation

The liquid portion of settled effluents can also b[e] spray irrigated on land without any trouble from nozzl[e] clogging (see fig. 4). No attempt has been made t[o] comminute the solids so that they can also be spraye[d] onto the land as in the case in the canning industry (4)

It is possible to employ overhead irrigation eve[n] during the coldest of winters with precautions take[n] to prevent freezing of equipment. The warm waste will keep the ground from freezing, except around th[e] periphery (3).

Settling basins

The separation of the liquid from the solids (mostl[y] starch) requires settling basins of one type or another.

Settling basins may be employed for holding th[e] effluent from the chip plant. A holding period of on[e] hour is sufficient for the removal of most of the starc[h] and large solids (approximately 50 percent of the tot[al] B.O.D.). If held for as much as 3 hours a B.O.D. r[e]moval of 60 percent has been reported. Table IV show[s] the reduction effected in a trial run made to suppl[y] data for this guide. For details of equipment require[d] consult the research division of the P.C.I.I.

A basin of this type may be constructed of concre[te] with manholes on top for cleaning. Periodic cleanin[g] of small basins may be accomplished by pumping th[e]

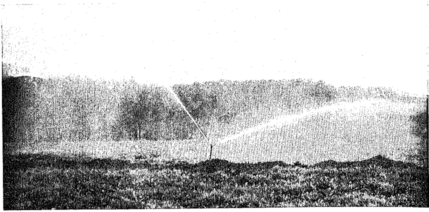


Figure 4.—Spray irrigation on alfalfa stubble. Wastes containing 220 p.p.m. solids, from settling basin are effectively disposed of by this system.

sludge from it, similar to the cleaning of a septic tank, and the solids then hauled to a field or some other dumping area. This will reduce the load going to the municipal sewage plant.

TABLE IV.—*Sample B.O.D. reductions effected by screening and settling*

	To vibrating screen	To settling basin	From settling basin after 3 hours
pH	5. 33	5. 74	5. 82
B.O.D., p.p.m	1, 760	1, 280	650
Suspended solids, p.p.m	5, 910	3, 350	226
Settleable solids, ml/L	270	26	Trace

Another method which has been used in the past is a system which operates similar to a plain settling basin but has automatic equipment for pumping out the sludge either to tanks or to a tank wagon. This is rather a costly method, but improvements have been made to make it more efficient.

Another method which could be considered is use of a settling tank, passing the effluent through a series of underground weepers similar to the drain tile installations attached to domestic septic tanks. It may be necessary to direct the effluent periodically from one group of weepers to another. The needed drainage requires a considerable amount of land space. Another point that must be considered in using this type of installation is the absorption characteristics of the soil. The absorption test of the soil will determine the area that will be needed to absorb the effluent from the settling tanks. One advantage of this method over a lagoon is that there are no odors.

Lagoons

In some areas lagoons may be used, providing the location of the lagoon does not result in an odor nuisance. Two lagoons should be used and when one becomes filled with residue, the effluent from the plant can be diverted into the second lagoon. When the first lagoon dries up a bulldozer may be used to remove the solids that have accumulated. If the odor from such a lagoon creates a nuisance, chemicals (usually certain soluble nitrogenous compounds) may be used to curtail it.

Stabilization ponds

One rather new development that may be of interest to a number of chippers who are located within 1 or 2 miles of available farm land, is the use of stabilization ponds. Ponds have been used throughout the world for many years to: (1) remove suspended matter; (2) regulate erratic waste flow patterns; (3) store wastes for release during high stream flows and to a lesser extent, store for later irrigation use; and (4) propagate fish with fertilized water. More recently (since

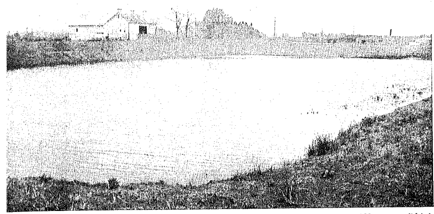


Figure 5.—Stabilization pond with a normal loading of 45 pounds B.O.D. (15,500 gal. of 200 p.p.m. solids) is stabilized daily by this pond which is 1 acre in size, 6 feet deep (deeper than desirable) and holding 1.9 million gallons. Overflow is through a wooded area into a nearby stream. An 83 to 93 percent reduction in C.O.D. has been secured during the summer months by the use of this pond.

1948) it has been recognized that stabilization ponds may provide a degree of purification comparable to that achieved by conventional complete treatment processes.

In stabilization ponds the organic matter is broken down into simpler compounds by means of bacteria. The decomposition products, in turn, are utilized by algae during photosynthesis to produce oxygen and additional algal mass. This oxygen then supplies that necessary for aerobic bacterial decomposition. Photosynthesis, and hence oxygen production, depends on available sunlight. This phenomenon ceases at night and is reduced by turbid water, an ice cover, or a cloudy day.

Under normal conditions, sufficient oxygen is produced during the daytime to supply the demands during the night. In addition to sedimentation of the settleable solids in the pond, suspended and colloidal solids may be precipitated by the action of soluble salts which are concentrated by evaporation in summer and freezing in the winter. The settled material subsequently undergoes decomposition.

The load in terms of total organic matter assimilated in stabilization ponds depends on many factors. Shallow (3 feet) ponds are more effective than deeper ponds. Ponds exposed to wind movements are more effective than those in sheltered areas. Loadings depend to a great extent on temperature and available sunlight and hence would vary with different climates. Loads of 10 to 120 pounds B.O.D. per acre per day have been recorded. In the only stabilization pond known to be used exclusively for chip wastes a load of 66 pounds of B.O.D. per acre per day has been effectively utilized during summer months (see fig. 5).

Trickling filters and chemical coagulation

Trickling filters have been employed for treating canning wastes although the seasonal operation of canneries makes it difficult to develop effective treatment units. Year-around operation of potato chip plants should permit more effective operation of trickling filters. Chemical coagulation (rather expensive) has been used fo[r] partial treatment where untreated wastes may overloa[d] small municipal treatment plants. With increasing im[portance] of satisfactory waste disposal, industrial site[s] that minimize the waste problem should be selected (se[e] figures 6 and 7).

Municipal plants

The most used and probably the best method of wast[e] disposal is that of discharging the sewage into a munic

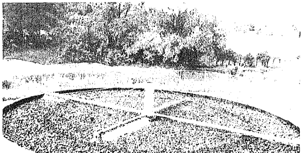


Figure 6.—Trickling filter.

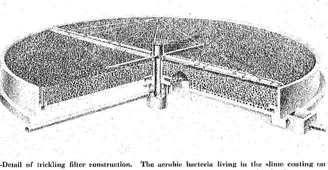


Figure 7.—Detail of trickling filter construction. The aerobic bacteria living in the slime coating on the stones "digests" the organic matter remaining in the wastes coming from the clarifier.

ipal system. In some instances the charges imposed for municipal handling of wastes are rather high.

In arriving at a cost charge it is well to remember that approximately 50 percent of the B.O.D. is produced by solids that can be removed (peels, trimmings and starch) by shaker screens or basket centrifuges. Another 25 percent of B.O.D. can be removed by settling tanks.

Equipment needed for disposal into municipal sewers consists essentially of a food chopper and adequate water to flush the wastes into a larger sewer.

B.O.D. vs. C.O.D.

Biochemical Oxygen Demand (B.O.D.) determinations are difficult to run and require considerable special equipment. The Potato Chip Institute International hopes to establish a correlation between B.O.D. and more easily determined C.O.D. (Chemical Oxygen Demand) analyses. A preliminary run of six samples (without a catalyst) by W. D. Sheets gave an average of 261 p.p.m. (parts per million) B.O.D. as compared to 317 p.p.m. of C.O.D. These data are not sufficient for practical usage. The use of a silver sulphate catalyst greatly increased the C.O.D. values.

Summary

The potato chipping process consists of peeling, trimming, slicing, washing, rinsing, drying, cooking, and packaging. Wastes originate primarily from the peeling, trimming, washing, and rinsing operations.

Representative data evolved from a study of several plants, based on 1,000 pounds of potatoes handled, were as follows:

Flow in gallons	B.O.D.		Suspended solids	
	Lbs.	P.P.	Lbs.	P.P.
1,990	25.4	152	33	165

Waste products vary with types of potatoes and methods of processing. If preliminary estimates of plant wastes must be made without a sampling study, it will be advantageous to evaluate the process based on dry solids in the potato and dry solids produced. Excellent correlation was obtained by comparing pounds of B.O.D. calculated from the weight of solids lost with the pounds of B.O.D. in the sewer. The average B.O.D., estimated from solids wasted per 1,000 pounds of potatoes, was 25.4 pounds as compared with an average B.O.D. of 25.0 pounds in the sewer per 1,000 pounds of potatoes.

A dry solids balance can be computed using the solids content of the potato and the pounds of chips produced, and allowing for the oil and moisture content of the finished chip. The pounds of dry potato solids lost times the factor 0.453 pounds B.O.D. per pound dry potato solids results in the pounds B.O.D. discharged. If all wastes reach sewerage, the above value will reasonably approach the B.O.D. of the discharged liquor. Should some solids be removed for manual disposal, the value must be adjusted accordingly.

A counter-current principle of water use would seem to hold promise for reduction of water consumption and of waste discharge. Although manual removal of solids reduces the waste load, the choice between manual and water-carried disposal is a matter of economics and cleanliness, and is one that management must make.

A residual amount of wastes will require disposal. Discharge to municipal sewerage, with or without chemical pre-treatment, is probably the best method. Other methods that might be considered are flood, furrow, and ditch irrigation, lagooning with land application or spray irrigation, stabilization ponds, and trickling filters. Industrial plant sites that minimize disposal problems should be selected.

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